CONFIGURATION ENVIRONMENT FOR THE ASDEX UPGRADE CONTROL SYSTEM

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Abstract

ASDEX Upgrade is a tokamak fusion device controlled by a network of real-time control computers. Magnetic field coils, fuelling and heating systems may be operated feedforward or used in various feedback control loops. The real-time control system is parameterized by a discharge program, i.e. a set of time varying value trajectories to choose among control algorithms, to define feedforward and feedback references and set control flow conditions. An environment to configure such a system has to be based on control and monitoring processes implemented in the currently installed discharge control software and on actually connected I/O hardware. A process oriented user interface for the input of reference values facilitates the physicist's orientation while assembling a discharge program.

1. INTRODUCTION

A fully digital discharge control system (DCS), such as that of ASDEX Upgrade, offers the advantage to continuously extend control options to flexibly fine tune control scenarios according to the envisaged discharge goal. However, this comes hand in hand with an increasing complexity of the control system structure and thus implies an increasing potential for errors in the configuration process.

After an overview of the discharge control system, this paper will focus on configuration issues, indicate potential sources for inconsistencies and show how a carefully designed configuration environment can help to avoid these.

2 THE DISCHARGE CONTROL SYSTEM

2.1. *Tasks*

The main tasks of the DCS are:

- Physics control, comprising position and shape control tasks and plasma performance control tasks, and
- Supervision control responsible for the overall coordination of the physics control tasks

Position and shape control computes a selected set of plasma equilibrium parameters from current and flux measurements and controls a selected subset of these parameters using the tokamak's vertical field coil system.

Although there is a sound theoretical base for multivariable control of the distant coils, the power and current limits and the mutual coupling make this a highly complex task. As a result stable feedback control for a given machine setup is only possible for specific subsets of shape parameters and by applying precisely calculated control parameters, gains and feedforward references [1].

Performance control accesses the various fuelling and heating systems to concurrently control parameters of plasma bulk, surface and divertor. The involved elementary single-variable feedback control processes and gain parameters are based on heuristic knowledge. Meaningful combinations of simultaneously operating single-variable processes are combined into a recipe [2], avoiding mismatch of actuators or control variables.

Supervision control tracks the overall system state, collecting the results of physical and technical monitoring processes. These range from simple threshold checks to complex detection of plasma states or instabilities. In case of alarms, instabilities, severe deviations from the schedule, or plasma states attained, alternate discharge program segments may be activated. As a reaction, specific sets of control processes or reference trajectories are applied to optimize discharge control performance [3].

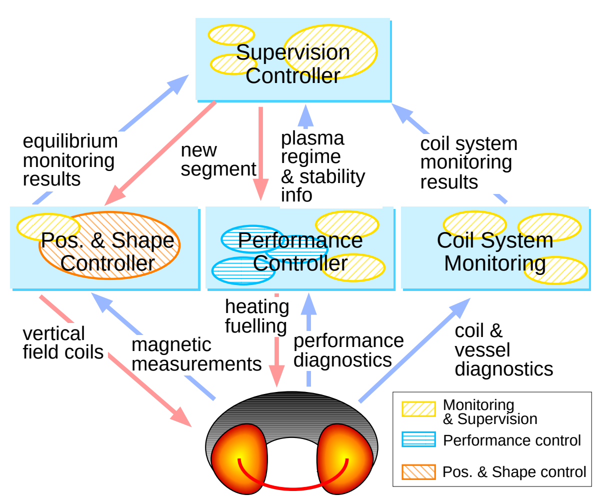

Figure 1: Discharge Control System

2.2. *Structure*

The structure of the DCS closely reflects the above described task decomposition [Fig 1]:

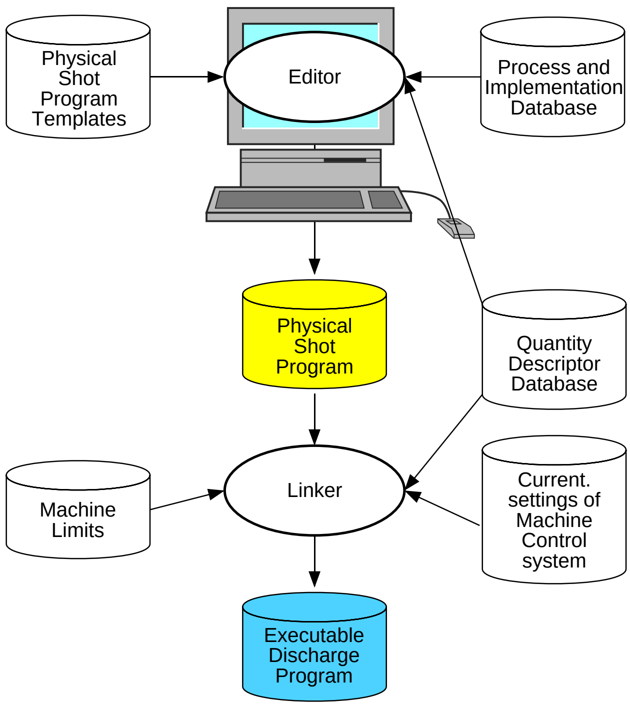

Figure 2: Assembly of a Discharge Program.

- The supervision controller performs simple monitoring tasks, collects results from these and from external monitoring processes in a bit-vector and compares it to active branching conditions
- The position and shape controller computes, controls, and monitors equilibrium parameters
- The performance controller performs control tasks involving fueling and heating, and evaluates plasma state and stability
- The coil system controllers perform the more complex monitoring of thermal, mechanical, and electrical stress of the toroidal and poloidal magnetic field coil systems

3 CONFIGURATION

The DCS is configured via the (executable) discharge program (DP) and private parameter files which are downloaded into the controllers prior to a discharge. All quantities in the DP have a unique identifier (QID) through which they are accessed by the DCS and the configuration environment. A record with attributes for each quantity is held in the quantity descriptor (QTD) database

3.1. Discharge Program

The DP is assembled in two steps: [Fig 2]

First, the experiment leader has to edit the physical shot program (PSP) – which embodies his/her idea of the evolution of a discharge - using the shot program editor (SPE). The SPE's graphical user interface is used to insert or modify the values of quantities that govern the physical aspects of the experiment to be performed. These are:

- Switches for the dynamic activation of processes and for the selection of control or monitoring parameters (recipes).
- Waveforms and constants required for the execution of activated control and monitoring processes (reference values, gain factors, thresholds...)

In a second step the PSP is linked with the following additional data:

- Technical parameters (constants) reflecting the current settings of the machine control system
- Machine limits, which are fixed and reflect the engineering design parameters of the experiment (max. coil currents, etc.)
- I/O information from the QTD database required for the correct de- and encoding of peripheral signals (actuator and sensor scaling, multiplex addresses, bit-positions...)

The DP is organized in segments representing distinct phases of a discharge. The segments are concatenated through execution conditions, which are evaluated in real-time against the current state of the experiment by supervision control.

A flag in the QTD record of each parameter indicates if the values for this parameter are to be created by editing or in the linking process

A detailed description of the DP data structure can be found in reference [4].

3.2. Requirements

To deliver the expected results a DP must fulfil several requirements. It should be

- Compatible with the currently installed software and peripheral hardware.
- Complete in that all activated processes should be fully parameterized.
- Free of internal contradictions (no two processes with conflicting objectives should be active)

The following examples illustrate these requirements:

- When an execution condition is used for supervision control all involved monitoring processes must be activated and correctly configured.
- When a performance control recipe is active, all participating elementary control processes must be correctly configured. (This usually implies that all actuators that are used by these processes must be made available to them).
- Position and shape control parameters monitored by some range-check process must be in the set of computed equilibrium parameters
- Reference values for controlled quantities which also serve as inputs for some monitoring

process should (normally) not exceed the monitoring processes thresholds

Another issue is the compatibility of the settings of machine control system with the requirements of the PSP. See reference [5] for an extensive treatment of this subject.

4 ENVIRONMENT

4.1. *Process and Implementation Databases*

To assist the experiment leader in editing a PSP that fulfils the above consistence and completeness requirements the editor must be „aware" of the software version the PSP is being edited for.

This is be achieved by defining a process and an implementation database.

Each process record contains

- The Process ID (PID), a unique identifier for the process.
- A process type identifier
- QIDs for all quantities used by the process
- A string describing the role of each parameter within the process (e.g. threshold, reference value, clipping value).

Implementation records contain:

- The release number of a controller software
- A list of the PIDs of the processes it implements
- Activation conditions (possibly "none" for processes which are always active) for each of the listed processes.

4.2. *Editor Configuration*

Whenever the editor is started, it is passed the release number of the current software. It can use this as a key to access the installation database and obtain a list of PIDs and activation conditions of all processes implemented by the software. The PIDs are used to retrieve QIDs and related signal information from the process database. Finally the QIDs are used to obtain signal descriptors from the QTD database.

4.3. *Editor Features*

Additional features for the editor support the experimentalist:

- It offers a process-oriented view of the configuration parameters.
- It offers a view oriented on actuator systems (Coil systems, heating systems, fuelling systems)
- It provides navigation facilities, e.g. from a process to an actuator feedforward signal
- It permits the generation of waveforms (e.g. creating limits of a range check monitoring process by specifying a reference waveform and a maximum deviation around it)
- It allows importing of waveforms from external sources. (This is be very useful for parameters computed by simulation)
- It warns when conflicts are recognized.

5 CONCLUSION

The complexity of the control tasks an their interdependence makes building a discharge program for the ASDEX Upgrade tokamak DCS a demanding task.

The introduction of process and implementation databases into the configuration environment helps to ensure that a discharge program is compatible with the current control software and the connected peripheral hardware.

An improved user interface for the PSP Editor helps to guide the experiment leader through the configuration process.

The described configuration environment both reduces configuration time in the experiment cycle and increases the likelihood of a successful discharge execution.

6 REFERENCES

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